

# A flexible pulsed ps/ns laser system for ion beam cooling at ESR/SIS100\*

T. Beck<sup>1</sup> and Th. Walther<sup>1</sup>

<sup>1</sup>Institute of Applied Physics, TU Darmstadt, Germany

Stored relativistic (heavy) ion beams for precise atomic physics experiments are typically cooled by means of electron and/or stochastic cooling, in order to achieve a small relative longitudinal momentum distribution  $\Delta p/p = 10^{-4} - 10^{-5}$ . Laser cooling was introduced as a third cooling method, because it can provide even colder ion beams. During beamtime at the ESR in 2004, 2006, and 2012,  $C^{3+}$  ion beams were stored and successfully laser-cooled [1]. During the latest beam time a cw laser system developed at TU Darmstadt was continuously scanned across the  $2S_{1/2} \rightarrow 2P_{1/2}$  transition of  $^{12}C^{3+}$  [2]. The kinetic energy of the ions was 122 MeV/u. A relative longitudinal momentum distribution of at least  $\Delta p/p = 10^{-6}$  was achieved.

One of the biggest challenges to face with laser cooling is to overcome heating due to intrabeam scattering (IBS). One option to suppress IBS is cooling all ions simultaneously. This technique is known as “white-light cooling” and employs a broad band pulsed laser systems (c.f. figure 1) [3,4].

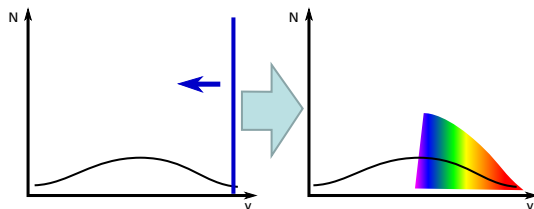


Figure 1: The general idea of white-light-cooling. Instead of tuning a narrowband continuous laser across the resonance cooling the individual velocity classes of the ions, a pulsed laser cools all ions simultaneously.  $N$  is the number of ions and  $v$  their velocity. Ideally the spectrum of the laser has a sharp edge towards the blue.

Here, we report on the progress of the development of a laser source for white-light cooling. The system will operate at 257 nm with a repetition rate of 1 MHz and a variable pulse length between 80 ps and 50 ns and nearly Fourier limited pulses. (c.f. figure 2). The flexible pulse duration will allow to tailor the output spectrum to match the velocity distribution of the ions.

An external cavity diode laser (ECDL) serves as the master oscillator. Its frequency is mode hop free tunable up to 37 GHz. The power of the ECDL is preamplified up to 9 W using a cw fiber amplifier. New pump laser modules enable very efficient amplification with a slope efficiency

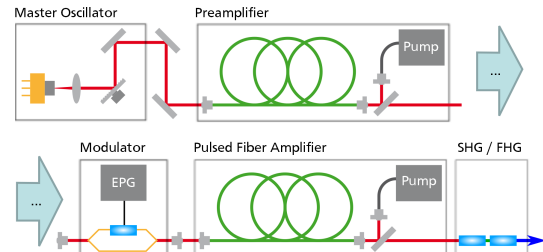


Figure 2: Schematic overview of the pulsed laser system. EPG: electronic pulse generator, SHG: second harmonic generation, FHG: fourth harmonic generation

of more than 65 %. After amplification, a table top modulator box, consisting of an AOM and two subsequent Mach-Zehnder type EOMs, cuts pulses with a variable length between 80 ps and 50 ns out of the cw laser beam. The box is completely fiber based and easy to integrate into the cw laser setup.

After the pulses are generated, they serve as a seed for the pulsed fiber amplifier. Currently, it only consists of one amplification stage, but more are to be added in the near future. In the first stage of the pulsed amplifier we reached up to 4.8 mW of average power at 80 ps and 500 mW at 50 ns. The suppression of amplified spontaneous emission was better than 10 dB and with a linewidth of 30 MHz the 50 ns pulses are nearly Fourier transform limited.

In conclusion, we are making good progress towards a new pulsed laser system for cooling relativistic ion beams. Upon completion of the system, tests at the ESR or the CSRe in Lanzhou are possible. In combination with the existing cw laser, smaller momentum spreads and a more stable long time operation are conceivable.

## References

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